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HOME RANGES AND HABITATS OF NORTHERN GOSHAWKS IN EASTERN CALIFORNIA

CHRISTINA D. HARGIS, CLINTON MCCARTHY, AND RICHARD D. PERLOFF

Abstract. We conducted a 3-summer telemetry study of nesting Northern Goshawks (*Accipiter gentilis*) (N = 10) to determine stand structure, landscape patterns, and geographic features that characterize home ranges. We subdivided home range use into two phases of the breeding season, the nestling phase and post-fledging phase, because home ranges of adult males and females showed significant expansion after the young had fledged. Nearly all birds incorporated areas into their home ranges that were spatially distant from the nest stand, which resulted in higher vegetative diversity within the nestling-phase home ranges than would be expected from random home range placement. Home range locations used by perched goshawks were similar to nest sites, and both had greater canopy cover, greater basal area, and more trees per ha than a random sample from the study area. Thus, perched goshawks tended to be in well-canopied stands with large trees that were in proximity to a variety of vegetation types and seral stages. Nest sites were significantly closer to water sources than random study area points, and home range configurations were influenced by the location of water. Goshawk management strategies should include the potential home range as well as the nest site. Our data suggest that a goshawk can incorporate vegetation types and water sources as far as 3.5 km from the nest stand into its home range. Within this potential use area, emphasis should be placed on creating or maintaining vegetative diversity. Mature forests should be retained around water sources, along forest-open edges, and throughout the potential foraging area.

Key Words: *Accipiter gentilis*; adaptive kernel; habitat use; home range; Northern Goshawk.

Much of the current knowledge of habitat use by the Northern Goshawk (*Accipiter gentilis*) has been taken from nest sites (e.g., Reynolds et al. 1982, Moore and Henny 1983, Kennedy 1988, Patla 1990). Little is known about habitat characteristics that define the rest of the home range, that is, the area used by individuals for foraging and resting as well as for care of young. Prior to the development of goshawk management recommendations for the southwestern United States (Reynolds et al. 1992), goshawk management in timber resource areas was generally limited to the retention of an uncut buffer of mature timber around nest sites, ranging from a recommended 8 ha (Reynolds et al. 1982) to 49 ha (Fowler 1988).

The emphasis placed on nest sites is justified because the nest or a nearby alternate nest is used by goshawks for many years (Palmer 1988). Protection of the nest and alternate nests provides a reasonable long-term management strategy. However, even though a nest site is protected, the remainder of the home range is frequently subjected to habitat alteration. If certain habitat components are needed by breeding goshawks in areas other than the immediate nest sites, then habitat alterations could eventually cause the decline of this species even though nest sites are protected.

Our study was prompted by the need to provide better management guidelines for goshawk home ranges within areas of timber management on the Inyo National Forest in eastern California. Beginning in 1979, goshawk nests on the Inyo National Forest were protected from timber harvests by delineating a 16-ha buffer around each known nest when the boundaries of each sale were mapped. This area was enlarged for all sales after 1987 to meet the guidelines of the Inyo National Forest Land Management Plan, which called for either a 40.5-ha buffer around the nest or two 20-ha buffers around the currently occupied nest and an alternate nest. One of our concerns was whether small, isolated buffers were sufficient to meet the needs of nesting goshawks, or whether other components within the home ranges needed to be considered. We needed to know where goshawks foraged in relation to their nests and what habitats were used for foraging, in order to make meaningful recommendations for extending management over areas larger than the nest buffers.

We investigated goshawk home range use at the microhabitat and landscape level. At the microhabitat level, we focused on the forest stand structure associated with goshawk telemetry locations within their home ranges. Other studies have shown that nest sites are typically in stands with large trees and dense canopies (e.g., Hall 1984, Speiser and Bosakowski 1987, Hayward and Escano 1989). We wanted to determine whether these conditions were also characteristic of areas used within home ranges.

At the landscape level, we were interested in vegetation patterns and landscape features that might influence the size, location, and configuration of home ranges. In particular, we wanted to determine whether home ranges were influenced by the location of large blocks of mature timber, the amount of vegetative diversity, the availability of interior habitat or habitat edge, the location of open areas, and the presence of water.

The objectives of our study were (1) to determine stand structure, landscape patterns and key geographic features that influence the size, location, and configuration of goshawk home ranges; and (2) to develop management recommendations focused on home range management rather than nest site management.

METHODS

STUDY AREA

The study area is approximately 440 km² of forested habitat on the Inyo National Forest, located east of Yosemite National Park near the California–Nevada border. Elevations range from 2000–2700 m. Extensive tracts of Jeffrey pine (*Pinus jeffreyi*) are interspersed with stands of lodgepole pine (*Pinus contorta*), big sagebrush (*Artemisia tridentata*), aspen (*Populus tremuloides*), and pumice flats sparsely vegetated with grasses and forbs. Red fir (*Abies magnifica*) is the dominant vegetation within the narrow elevational band of 2600–2700 m along the eastern Sierra slope. Red fir is also found in Jeffrey pine and lodgepole pine stands on many north- and east-facing slopes.

Most stands in the study area have 1–3 age classes of trees and a shrub or grass-sedge understory. The dominant ground vegetation in Jeffrey pine stands is bitterbrush (*Purshia tridentata*). A sparse cover of grasses (*Sitanion hystrix, Stipa occidentalis*) and sedge (*Carex rossii*) occur in lodgepole pine stands. Forest canopies tend to be open due to xeric conditions imposed by poor soils and climate (20–40 cm annual rainfall).

Much of the landscape has been modified by timber harvests, mostly through the removal of large diameter overstory trees, leaving mid-seral stage stands. Clearcuts are uncommon and are restricted to patches <16 ha.

For the purpose of this paper, older seral stages of timber will be referred to as "old growth." A formal old growth definition has not been developed for the Inyo National Forest, but old growth Jeffrey pine is typically >250 years old, with ocular-estimate canopy closures rarely >40%. Lodgepole pine old growth is >200 years old, with canopy closures between 30–50%. Red fir old growth is >250 years old, with canopy closures between 35–60%. Timber compartment stands identified as old growth on the Inyo National Forest (Inyo National Forest unpubl. stand record cards) are mostly 15–60 ha in size except for the 486-ha Indiana Summit Research Natural Area, managed for old growth Jeffrey pine, and a 900-ha tract of red fir, lodgepole pine, and white fir (*Abies concolor*).

HOME RANGES

Home range and habitat use data were derived from radiotelemetered goshawks during the summer seasons of 1986–1988. We captured goshawks using a dho-gaza with a Great Horned Owl (*Bubo virginianus*) lure in the vicinity of active nests (Hamerstrom 1963, Bloom et al. 1992). Each goshawk was banded with a US Fish and Wildlife Service leg band. Radio transmitters were attached to the backs of the birds with teflon tubing fitted around the wings. The 28-g transmitters had a life expectancy of 7 months.

We created a grid overlay for 1:24,000-scale USGS maps of the study area and used the grid coordinates in calculating goshawk locations. The spacing of 1 mm between grid lines corresponded to 26 m on the ground. Telemetry locations were obtained by two observers using Telonics 2A (Mesa, Arizona) and Advanced Telemetry Systems (Isanti, Minnesota) receivers and 5-element yagi antennae mounted in two truck beds. Simultaneous bearings were taken from two locations, and the estimated location of the bird was calculated by triangulation (White and Garrott 1990) using the two bearings and the known grid coordinates of the observers. We took bearings on each goshawk at 15-min intervals for 1.5 hr. Each bird was monitored every 2–3 days at a randomly selected time between 08:00–14:00.

To determine errors associated with location estimates, the observers estimated the location of a transmitter placed at 20 random locations by an independent party. The observers were on average 718 ± 368 (SD) m from the transmitter during these tests, and the mean error in location was 102 ± 66 m. The error associated with estimation of goshawk locations may have been somewhat lower, since during monitoring the observers were on average closer to the goshawks ($\bar{X}$ = 465 ± 292 m) than to the test transmitter. By proportional extrapolation, the mean error in estimating goshawk locations was 66 m.

Home ranges were calculated using an adaptive kernel method (Worton 1989) developed by J. Baldwin (USDA Forest Service, Pacific Southwest Experiment Station, Berkeley, California, pers. comm.). This method is based on Anderson's (1982) definition of home range: the probability of finding an animal at a particular location on a geometric plane, given a bivariate probability density function for that animal. The kernel method is a non-parametric technique that estimates the probability density function from a data set of known locations, using a data smoothing function similar to the Fourier transformation employed by Anderson (1982). The adaptive kernel method differs from the Fourier transformation and from fixed kernel methods in that the magnitude of the smoothing parameter is changed depending on the concentration of data points. Areas with a low concentration of points have less weight than frequently used areas, thereby rounding off finger-like extensions of the home range that are caused by a few location points (Worton 1989). All of these methods calculate a three-dimensional volume for the bivariate probability function from which contours can be selected that represent a given percentage of the volume, or a given percentage of the sample points. For the adaptive kernel method, our contours were constructed to represent a percentage of the sample points.

Contour intervals that represented 95% and 50% of each goshawk telemetry data set were constructed at the 1:24,000[redacted]e and traced onto mylar overlays of the study area. We calculated home range estimates for the entire monitoring period from late June to mid September. However, we found that these home range estimates were misleading because they included areas that were not used by the adults until the young had fledged. Also, these estimates masked information on home range shifts and range expansion that occurred after the young had fledged. A division of the monitoring period into two phases, nestling and post-fledging, provided a more sensitive discrimination of home range use, and separated the restricted, nest-oriented home ranges of the earlier period from the broader areas used later in the breeding season. Since observations at the nests indicated that all young had fledged by the end of July, we used 1 August to delineate the two periods and calculated nestling-phase and post-fledging-phase home range estimates for each bird.

Landscape Patterns

Landscape patterns were compared between nestling-phase home ranges, post-fledging-phase home ranges, and a random sample of artificial home ranges within the study area. Artificial home ranges were created by placing a circle with an area of 9.04 km² at random points within all available habitat of the study area. The centers of the artificial home ranges were grid coordinates that were generated randomly from the entire study area. The size of the circle corresponded to the mean size of the 95% polygons for the nestling-phase and post-fledging-phase home ranges. Within each randomly-placed circle and within the 95% contour of each home range, we recorded the number of vegetation types per km², total number of vegetation units (patches) per km², percent of home range in inventoried old growth, length of forest-open edge per km², distance to water, and distance to a forest opening greater than 20 ha. Vegetation types were qualitatively differentiated on the basis of the most abundant overstory and understory species (Mueller-Dubois and Ellenberg 1974) and seral stage (Mayer and Laudenslayer 1988). Vegetation boundaries were delineated using aerial photogrammetry and were field verified. Old growth acreages were derived from a comprehensive old growth inventory conducted on Inyo National Forest in 1989-1990 (Inyo National Forest, unpubl. data).

All distance measurements were taken from 1:24,000 orthophotos with a map wheel. Since the home range polygons were not circular, we developed the following criteria for selecting the point from which distances to water and forest openings were measured. For nestling-phase home ranges, distances were measured from the nest, whether or not the nest was the geometric center of the range. If the range contained other polygons besides the polygon containing the nest, we measured distances from the center of the other polygons and averaged the values. The center of each polygon was the midpoint of the longest axis bisecting the polygon. For post-fledging-phase home ranges, we measured distances from the center of the 50% contour located inside the 95% contour. In the majority of cases, the home range was a cluster of 2–3 polygons, so 2–3 distance measures were taken and averaged.

We noted whether home ranges encompassed or were in proximity to human developments, but did not quantify these relationships. Principal developments were the town of Mammoth Lakes (pop. 10,000), highways, developed campgrounds, and major dirt roads.

Stand Structure

As a means of evaluating stand structure used within home ranges and at nests, we collected data at three types of sites: nest sites, sites within the home ranges other than nest sites, and sites located at random within the study area. The nest site data included the nests of the radio-tracked birds and all other known goshawk nests within the study area. The home range data set was a stratified random sample of all radio telemetry locations other than nest sites for the three summer seasons of study. We stratified the data to ensure that some locations were derived from all ten birds that were monitored. The sample was taken from the entire monitoring period. Random sites were selected by generating random x,y coordinates from the study area grid overlay.

Plot size used to measure stand structure variables was 0.04 ha. At each nest we collected data at five plots to include local variation in stand structure parameters. One plot was centered on the nest tree and the remaining plots were located 30 m from the tree in each of the cardinal directions.

Home range telemetry points were located in the field using the estimated grid locations placed over the study area map. We began collecting data at home range locations prior to selecting a method for determining the error associated with estimation of these points. We assumed that our error ranged from 25–75 m from the true locations of the birds and collected data at two plots at random distances between 25–75 m from the calculated telemetry location. The stand structure values obtained from both plots were then averaged. These distances proved to be close to the 66 m error that we calculated later. The two points also helped capture some of the variation found within the forest stands. Time constraints did not permit collecting data at more than two plots per location. We located the random sites in the field and collected data in the same manner as at home range sites, using two plots located 25–75 m from each random point.

Habitat parameters collected in each plot for all three site types were used to assess stand density and the amount of standing and down dead material. These included number of trees in five diameter classes (1–15 cm, 16–27 cm, 28–45 cm, 46–61 cm, and >62 cm), basal area, percent canopy cover, percent slope, aspect, and number of snags and down logs within each plot. Basal area data were collected with a 20-factor basal area prism. Percent canopy cover was the average of four ocular estimates made within the major quarters of each circular plot. Percent slope was taken with a clinometer. At nest sites we also took data on nest tree diameter at breast height (dbh) (cm), nest tree height (m), and height of nest (m) within the tree. The dbh measurements were taken with a logger's tape. Tree and nest heights were derived from a clinometer reading taken at a known distance from the tree bole.

Prior to statistical analyses, all variables were examined for normality and transformed when appropriate. The square root transformation was applied to all count data, and an arcsine square root transformation was done for canopy closure proportions. Normal probability plots for the transformed data were linear, indicating that the transformations were appropriate. Univariate ANOVA procedures were used to test for stand structure and landscape level differences. We used Tukey's studentized range tests to determine which group or groups were responsible for any significant differences detected with the ANOVA tests.

TABLE 1. Selected Landscape Attributes for Goshawk Nestling-phase [redacted], Post-fledging Ranges and Random Circles within the Study Area

Landscape attribute	Nestling-phase ranges $\bar{x}$	SD	Post-fledging ranges $\bar{x}$	SD	Random $\bar{x}$	SD
No. of veg types/km	1.4	1.2	0.8	0.8	0.6	0.2
No. of patches/km	2.3	0.9	1.7	0.5	1.2	0.4
Km edge/km	1.1	0.7	1.2	0.3	0.9	0.4
Dist. to water (km)	1.2	0.9	2.2	1.2	2.7	1.2
Dist. to openings >20 ha (km)	0.7	0.6	0.6	0.3	0.7	0.6
Proportion of range in old growth	0.17	0.29	0.09	0.12	0.09	0.09

RESULTS

We radio tracked eight females and two males over the three summer seasons of the project: two females and one male in 1986, three females in 1987, and three females and one male in 1988. These ten adults were associated with six territories. Two of the territories were monitored twice, but with different females and alternate nests. The male in 1986 was the mate of a monitored female in the same year, and the male in 1988 was associated with the nest used by a monitored female in 1987. A female from 1987 was recaptured and followed again in 1988 but the second year of data was omitted from all statistical analyses and home range estimates. The number of telemetry locations per bird ranged from 35-56 during the nestling phase ($\bar{X} = 44 \pm 7$) and from 48–107 locations during the post-fledging phase ($\bar{X} = 64 \pm 18$). For the entire monitoring period, the mean number of telemetry locations was 108 ± 17 per bird.

Home Ranges

All home range estimates presented are for the areas of the 95% polygons. Home ranges for all ten adults for the entire monitoring period averaged 15.5 ± 8.9 km². The seven female home ranges averaged 13.4 ± 8.1 km², and the two male ranges were 17.9 km² and 30.1 km².

After approximately 1 August, we noted a significant range expansion (one-tailed paired-sample t-test, $t = 2.4$, $df = 9$, $P = 0.04$). This expansion was not correlated with the number of telemetry points associated with each bird (adjusted $r^2 = 0.12$). All but one female expande their home ranges. Female home ranges i creased from a mean of 5.2 ± 3.9 km² (range 0.7–7.8 km²) during the nestling phase to 10 ± 8.2 km² after the young had fledged (range 1.1–24.6 km²). The two males also expanded the ranges, from 3.4 km² to 16.2 km², and from 9 km² to 28.4 km². One female's range decreas from 7.8 km² during the nesting period to 1 km² after the young had fledged.

Four of the ten goshawks showed comple range shifts after the young fledged. The mc extreme case was the shift of one female to a area 9 km from her nest. Her post-nesting ran had roughly a 90% overlap with another radi tracked female. The female who did not expa her range shifted her area of use by appro mately 6 km to the vicinity of a playing fiel This female exhibited the same range shift in tv consecutive breeding seasons.

In relationship to human activities other th timber harvests, the 50% polygon for one nesti range included a 20-unit campground. Three the post-nesting ranges were divided by a 4-la highway, and one post-nesting range include playing field adjacent to the town of Mammc Lakes.

Landscape Patterns

We compared landscape patterns between th groups: nestling-phase home ranges (N = 1 post-fledging-phase home ranges (N = 10) a randomly-placed circles (N = 10). Using AN VA and $\alpha = 0.1$, we detected significant diff ences in the number of vegetation types per k between the 3 groups ($F = 2.53$, $df = 29$, P 0.1). A Tukey's studentized range test at $\alpha =$ indicated that nestling-phase home ranges l on average a greater number of vegetation ty per km² than the random circles. The mean nu ber of vegetation types per km² for post-fledg phase ranges was less than that found in nestli phase home ranges and greater than that fo in random circles, but was not statistically ferent from either of these groups (Table 1). There was no significant difference in the number of patches per km² ($F = 2.29$, $df = 27$, $P = 0.12$), although we noted a trend similar to that found with vegetation types; nestling-phase home ranges had the greatest number of patches per km² and random circles had the lowest number (Table 1). As measured by these two variables, goshawk home ranges during the nestling phase appeared to contain more vegetative interspersion than would be expected if their ranges had been located at random in the study area. After the young had fledged, home ranges tended to maintain higher vegetative diversity than expected.

The configurations of nearly all home ranges supported this conclusion, since seven out of the ten monitored birds had areas of concentrated use that were spatially distant from the nest stand during the nestling phase (Fig. 1). These areas were disjunct polygons of the 95% home range area and contained vegetation types and seral stages that were not present in the polygon around the nest.

For two birds, this additional polygon included a large pumice flat (a different pumice flat for each bird). In four cases, the second polygon added seral stages of Jeffrey pine that were not present within the nesting polygon, and in the remaining case, the second polygon added riparian vegetation.

During the post-fledging phase, eight of the ten birds had disjunct home ranges at the 95% level. There were three instances where the additional clusters of telemetry points were associated with water sources and riparian vegetation, two which added extensive edge along large pumice flats, one that added old growth not present in the nest polygon, one that added moderately stocked young forest, and one that added a baseball field adjacent to mature forest.

One female selected a vegetatively diverse area approximately 3.5 km east of her nest rather than including more of the available old growth that surrounded her nest. This caused her post-nesting range to be two disjunct use areas divided by a 4-lane highway (Fig. 2). The majority of telemetry points for this female were along a forest-pumice flat edge and in the adjacent stand of old growth. There were no other active goshawk territories within the old growth around her nest that might have caused her to forage elsewhere. However, her range overlapped that of a second monitored female who used the same pumice flat and surrounding forest.

These disjunct polygons were not an artifact of our monitoring method of taking six consecutive readings per day. When we calculated the home ranges using one location per day, we ob-

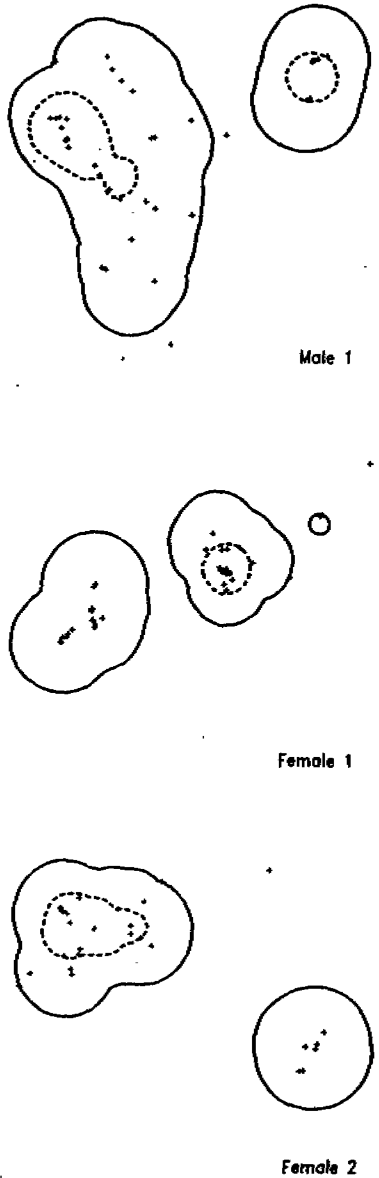

FIGURE 1. Examples of three goshawk nestling-phase home ranges from eastern California, showing clustering of telemetry points and disjunct polygons representing 95% (solid lines) and 50% (dashed lines) of telemetry locations.

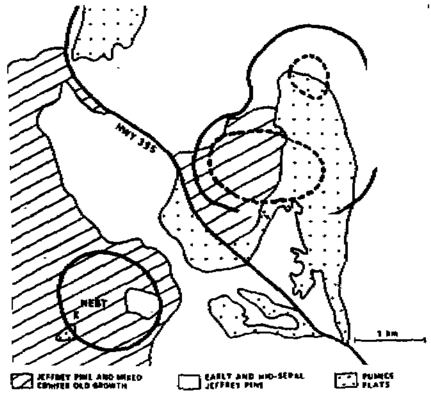

FIGURE 2. Post-fledging phase home range of a female goshawk in eastern California, showing selection for forest edge along a large pumice flat. The solid and dashed lines encompass 95% and 50% of the telemetry locations, respectively.

FIGURE 3. Nestling-phase home range of a female goshawk in eastern California, showing elongation of the home range to include the nearest source of water, 3.5 km from the nest. The solid and dashed lines encompass 95% and 50% of the telemetry locations, respectively. Note that a portion of the 50% contour is around the spring.

served polygons that maintained the same spatial arrangement and similar configuration as the home range estimates generated from six consecutive locations per day.

We also detected significant differences between the three groups in the distance to water ($F = 3.22$, $df = 29$, $P = 0.06$). The nests were on average closer to permanent water sources (springs and small streams) than were the centers of the post-fledging ranges or the artificial home range circles (Table 1). Six birds had water within the polygon containing the nest, and in one case, the home range polygon was extremely elongated to include a spring located 3.5 km from the nest (Fig. 3). In this case, 50% of the locations were divided between the nest stand and this spring. One female did not use the permanent water within her nest polygon, presumably because it flowed through open meadows, but she consistently used a water source 3.3 km from her nest in mature Jeffrey pine, thereby creating a second polygon that defined her home range at the 95% level (Fig. 4).

Stand Structure

We collected stand structure data at 20 nests, 63 home range sites (telemetry locations), and 102 random sites within the study area. The nest data set included three situations where data were collected on more than one nest in a territory (alternate nests). The inclusion of these nests may affect the assumption of independence. We included these nests because they were not in the same vegetation polygon as the active nest and our banding records indicated they were used by different females.

Five of the eight variables examined with ANOVAs were significantly different at $\alpha = 0.05$: basal area ($F = 47.74$, $df = 184$, $P < 0.01$), canopy cover ($F = 31.66$, $df = 184$, $P < 0.01$), pole-sized trees 16–27 cm dbh ($F = 11.55$, $df = 184$,

FIGURE 4. Nestling-phase home range of a female goshawk in eastern California, showing use of a water source located approximately 3.3 km north of the nest. The solid and dashed lines encompass 95% and 50% of the telemetry locations, respectively.

TABLE) STRUCTURE VARIABLES FOR GOSHAWK NEST SITES, USE SITES WITHIN HOME RANGES, AND RANDOM SITES WITHIN THE STUDY AREA

	Nest sites		Home ranges		Random	
Variable	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Basal area (m^2/ha)[1]	37	9	39	12	26	13
Canopy cover (%)[1]	31	13	34	16	21	15
Slope (%)	12	11	7	9	10	13
Timber class (trees/ha)[2]						
1	16.1	11.6	11.6	11.0	10.1	10.1
2[1]	6.9	7.9	6.5	5.2	4.2	3.8
3	3.5	1.8	3.4	2.7	2.6	2.8
4[1]	1.8	1.0	1.7	1.5	1.0	1.0
5[1]	1.3	0.7	1 2	1.2	0.8	1.0

[1] Indicates differences in mean values between random sites and the two goshawk data sets (alpha = .05/3) using Tukey's studentized t-test.
[2] Timber classes correspond to the following dbh sizes: timber class 1: 1–15 cm; timber class 2: 15–27 cm; timber class 3: 28–45 cm; timber class 4: 46–61 cm; timber class 5: >62 cm.

$P < 0.01$), and the two largest tree diameter classes ($F = 18.42$ and $F = 47.74$, $df = 184$, $P < 0.01$). Goshawk nest sites and the surrounding home range telemetry points had greater basal area, more canopy cover, and more trees in these three diameter classes than the random plots in the study area (Table 2). For all of the above variables, the Tukey's test for differences among means separated the random plots from the home range telemetry plots and the nest sites ($df = 27$, $P < 0.05$) but did not distinguish between the home range plots and the nest sites. Forest structure selected by goshawks within their foraging ranges was similar to forest structure within the nest stands, and both differed significantly from random plots.

NEST TREE CHARACTERISTICS

Goshawk nests were in lodgepole pine, Jeffrey pine, and red fir, with a mean tree height of 28.0 ± 6.73 m and a mean dbh of 87.2 ± 27.2 cm. The average diameter was within the largest diameter class used in this study and was therefore in the upper range of tree diameters found within the study area. The mean nest height was 11.6 ± 2.33 m. Canopy cover immediately around the nest tree averaged 29% ± 12.6%.

DISCUSSION AND MANAGEMENT IMPLICATIONS

Goshawk home ranges in our area tended to be located in areas with high vegetative and seral diversity, especially during the nestling phase. The disjunct nature of many of the home ranges appeared to increase the number of vegetation types incorporated into the birds' foraging areas. By using areas that were geographically removed from their nest stands, goshawks were able to include vegetation types and patterns that were generally uncommon, such as riparian vegetation, wet meadows, and old growth stands adjacent to meadows or pumice flats.

Nest sites and telemetry locations were associated with forest stands that had higher basal area, more canopy cover, and more trees per ha than the study area average. The telemetry locations were not necessarily foraging locations, because bearings were taken when the signals were stationary, and represented times when the birds were perched. Our telemetry data indicated that perched goshawks tended to be found in well-canopied stands with large trees. These locations may have provided hunting perches thermal cooling, or protective cover.

The proximity of these locations to a variety of vegetation types and seral stages may have been related to prey availability. Reynolds et al. (1992) reported a medium to high degree of vegetative interspersion for 13 of 14 selected goshawk prey species. Although we lack dietary information for our monitored goshawks, 12 of the prey discussed in Reynolds et al. (1992) are found in our area. The selection of areas with high diversity corresponds to the degree of interspersion used by common goshawk prey species.

Goshawk home ranges in our area were influenced by the location of permanent springs and small streams. The value of water for goshawks has been variously reported in the literature. Speiser and Bosakowski (1987) found no significant difference in the proximity of water to goshawk nests and random plots, and Crocker-Bedford and Chaney (1988) reported that only 8 out of 43 nests were <1 km from water. Other studies have reported distances of <275 m (Shuster 1980), <600 m (Reynolds et al. 1982), and <1 km (Kennedy 1988).

In areas where permanent streams and springs are uncommon, it may be difficult for all nesting goshawks to establish territories in proximity to

water. In these situations, the nearest available well-canopied water source should be viewed as potentially within the range of active nests that are not near water. Our study indicated that goshawks could incorporate water sources into their home ranges from as far as 3.5 km away.

Goshawks nested in stands that were substantially more open than those used in other geographic areas. The mean canopy closure of 29% at nest sites is far below the values of 88%, 81% 79%, 63% and 60% found in northwestern California (Hall 1984), northern California (Saunders 1982), northern Arizona (Crocker-Bedford and Chaney 1988), northwestern Utah (Hennessy 1978), and eastern Oregon (Reynolds et al. 1982), respectively. Dissimilar methods in measuring canopy cover may account for some of the difference.

Regardless of the absolute values, goshawks in our study selected stands that were denser than the average available, both for nesting and foraging, as measured by basal area, canopy closure, and the number of trees in all five diameter classes. Although absolute values may not be applicable to all geographic areas used by goshawks, the selection for stands with the most canopy cover and largest diameter trees can be translated to the site potential for different regions.

Goshawk management that focuses solely on nest sites assumes that goshawks are not selective in their use of habitats other than nest location. Yet our study indicates that goshawks select areas that are vegetatively diverse for foraging, including numerous aggregations of mature trees for nest stands and perch sites. Timber harvests on the Inyo National Forest typically remove the overstory, but numerous aggregations of mature timber are left for archeological site protection, deer hiding cover, snag recruitment, and riparian habitat. Although goshawk management is primarily limited to nest site buffers, these other management actions have resulted in the retention of mature timber and more vegetative diversity than would be expected under most prescriptions using overstory removal. All goshawk territories associated with timber sales have been active for approximately two-thirds of the years since the harvests, based on our nesting records over the past 14 years. Typically these territories have produced 2–3 young per nest.

Timber harvests can be compatible with goshawk conservation if key features such as permanent water sources, well-canopied stands of mature trees, and mature forest edge are provided within potential goshawk home ranges. Home range configurations cannot be determined with telemetry, but our data suggest that vegetation types and water sources as far as 3.5 km from the nest stand can [redacted]ewed as potential forag range, especially if these features are not prese near the nest.

An effective goshawk conservation strate would consider the potential home range as ciated with each nest site. Within this area, e phasis should be placed on creating or ma taining vegetative diversity, retaining matu timber around permanent water sources and alo forest-open edges, and ensuring that a portion the range provides forest stands that have str tural attributes similar to those found at the n site T[illegible] particular geographic area. Th mature stands would provide adequate perch s near or within selected foraging areas. We r ommend that timber harvests be designed to c ate a juxtaposition of seral stages, including n ture forests, rather than leaving large tracts homogeneous, mid-seral stage stands.

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